A NEW VEGETATION MAP OF THE WESTERN SEWARD PENINSULA, ALASKA, BASED ON ERTS-1 IMAGERY

James H. Anderson
Institute of Arctic Biology
University of Alaska
Fairbanks, Alaska 99701

and

Albert E. Belon
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701

February 1973
Interim Scientific Report, Contract NAS5-21833

(E73-10305) A NEW VEGETATION MAP OF THE WESTERN SEWARD PENINSULA, ALASKA, BASED ON ERTS-1 IMAGERY Interim Scientific Report (Alaska Univ., Fairbanks.) 22 p HC $3.25 CSCL 08B G3/13

N73-18337

Unclas 00305

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Goddard Space Flight Center
Greenbelt, Maryland 20771

22

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A New Vegetation Map of the Western Seward Peninsula, Alaska, Based on ERTS 1 imagery		5. Report Date February 20, 1973
		6. Performing Organization Code
7. Author(s) James H. Anderson and Albert E. Belon		8. Performing Organization Report No.
9. Performing Organization Name and Address Institute of Arctic Biology and Geophysical Institute University of Alaska Fairbanks, Alaska 99701		10. Work Unit No.
		11. Contract or Grant No. NAS5-21833
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION Goddard Space Flight Center Greenbelt, Maryland 20771		13. Type of Report and Period Covered Interim Scientific Report
		14. Sponsoring Agency Code

15. Supplementary Notes
ERTS-1 Projects nos. 110-1 and 110-3
NASA Technical Monitor: Edward C. Crump
NASA Scientific Monitor: Grover C. Torbert

16. Abstract A reconstituted, simulated color-infrared ERTS-1 image covering the western Seward Peninsula was prepared and it is used for identifying and mapping vegetation types by direct visual examination. The image, NASA ERTS E-1009-22095, was obtained approximately at 1110 hours, 165° WMT on August 1, 1972.

Seven major colors are identified. Four of these are matched with units on existing vegetation maps: Bright red = shrub thicket; light gray-red = upland tundra; medium gray-red = coastal wet tundra; gray = alpine barrens. The three colors having no map equivalents are tentatively interpreted as follows: Pink = grassland tundra; dark gray-red = burn scars; light orange-red = senescent vegetation.

A vegetation map, drawn by tracing on an acetate overlay of the image is presented. Significantly more information is depicted than on existing maps with regards to vegetation types and their areal distribution. Furthermore the preparation of the new map from ERTS imagery required little time relative to conventional methods and extent of areal coverage.

17. Key Words (Selected by Author(s))	18. Distribution Statement
ERTS imagery Vegetation mapping Alaskan environment and resources	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	20	

A NEW VEGETATION MAP OF THE WESTERN SEWARD PENINSULA, ALASKA, BASED ON ERTS-1 IMAGERY

by

James H. Anderson and Albert E. Belon

ABSTRACT

A reconstituted, simulated color-infrared ERTS-1 image covering the western Seward Peninsula was prepared and it is used for identifying and mapping vegetation types by direct visual examination. The image, NASA ERTS E-1009-22095, was obtained at 1110 hours (165° WMT) on August 1, 1972.

Seven major colors are identified. Four of these are matched with units on existing vegetation maps: Bright red - shrub thicket; light gray-red - upland tundra; medium gray-red - coastal wet tundra; gray-alpine barrens. The three colors having no map unit equivalents are tentatively interpreted as follows: Pink - grassland tundra; dark gray-red - burn scars; light orange-red - senescent vegetation.

A vegetation map, drawn by tracing on an acetate overlay of the image, is presented. Significantly more information is depicted than on existing maps with regard to vegetation types and their areal distribution. Furthermore, the preparation of the new map from ERTS imagery required little time relative to conventional methods and the extent of areal coverage.

Conclusions are (a) ERTS imagery is useful for studying diversity and distribution of vegetation types, (b) it is a feasible basis for drawing or revising vegetation maps, (c) sequential imagery should permit evaluation and monitoring of vegetation fires and phenologic events and (d) direct visual examination of ERTS-1 imagery, in lieu of more sophisticated analytical procedures, can enable significant interpretations.

TABLE OF CONTENTS

INTRODUCTION

One of the most urgent needs in Alaska today is a capability for environmental surveys and resource inventories on a scale suitable for regional land-use planning. This need is presently confronting many state and federal agencies concerned with resource management and it has led to the establishment by act of Congress through the Native Land Claims Settlement Act of 1971 of the Federal-State Land-Use Planning Commission.

Alaska is so vast and the arctic-subarctic environment so varied that the required surveys cannot be obtained in an adequate, timely and cost effective manner by conventional means. The Earth Resources Technology Satellite with its capabilities for rapid and economical surveys can assist greatly in this task. This potential would be further enhanced if it could be demonstrated that a resource specialist equipped with ERTS imagery and limited ground truth data, but otherwise unaided by sophisticated equipment and techniques, could produce regional environmental surveys and resource inventories with the required spatial resolution and accuracy.

Vegetation is a primary component of most landscapes and ecosystems and is one of the most important land resources. Knowledge of the composition, structure, distribution and environmental relationships of vegetation or vegetation types is therefore a key requisite in approaching land resource problems. In Alaska vegetation knowledge is sparse. The ERTS-1 project, of which the activity reported here is a part, is designed to develop imagery interpretation capabilities, to increase vegetation knowledge and thus to contribute to the handling of land resource problems.

This report deals with an attempt to identify and map vegetation types represented on an ERTS-1 (Earth Resources Technology Satellite) image of the western Seward Peninsula, Alaska, by direct visual examination. The image, NASA ERTS-E-1009-22095, was obtained at 1110 hours (165° WMT) on August 1, 1972. The format used is a 16 X 17 cm (approximate scale, 1:1,083,400) simulated color-infrared photographic print, reconstituted from MSS (multispectral scanner) bands 4, 5 and 7 in the photographic laboratory of the Geophysical Institute of the University of Alaska. Preparation of the print is described in the following section. Information on the characteristics of the ERTS satellite and its sensors is available in the ERTS Data Users Handbook (National Aeronautics and Space Administration 1971). The image covers that part of the peninsula lying west of a line running north-northeast from the coast a short distance east of Nome to the headwaters of the Goodhope River, and south of a line thence west-northwest through the east end of Shishmaref Inlet (Figure 1).

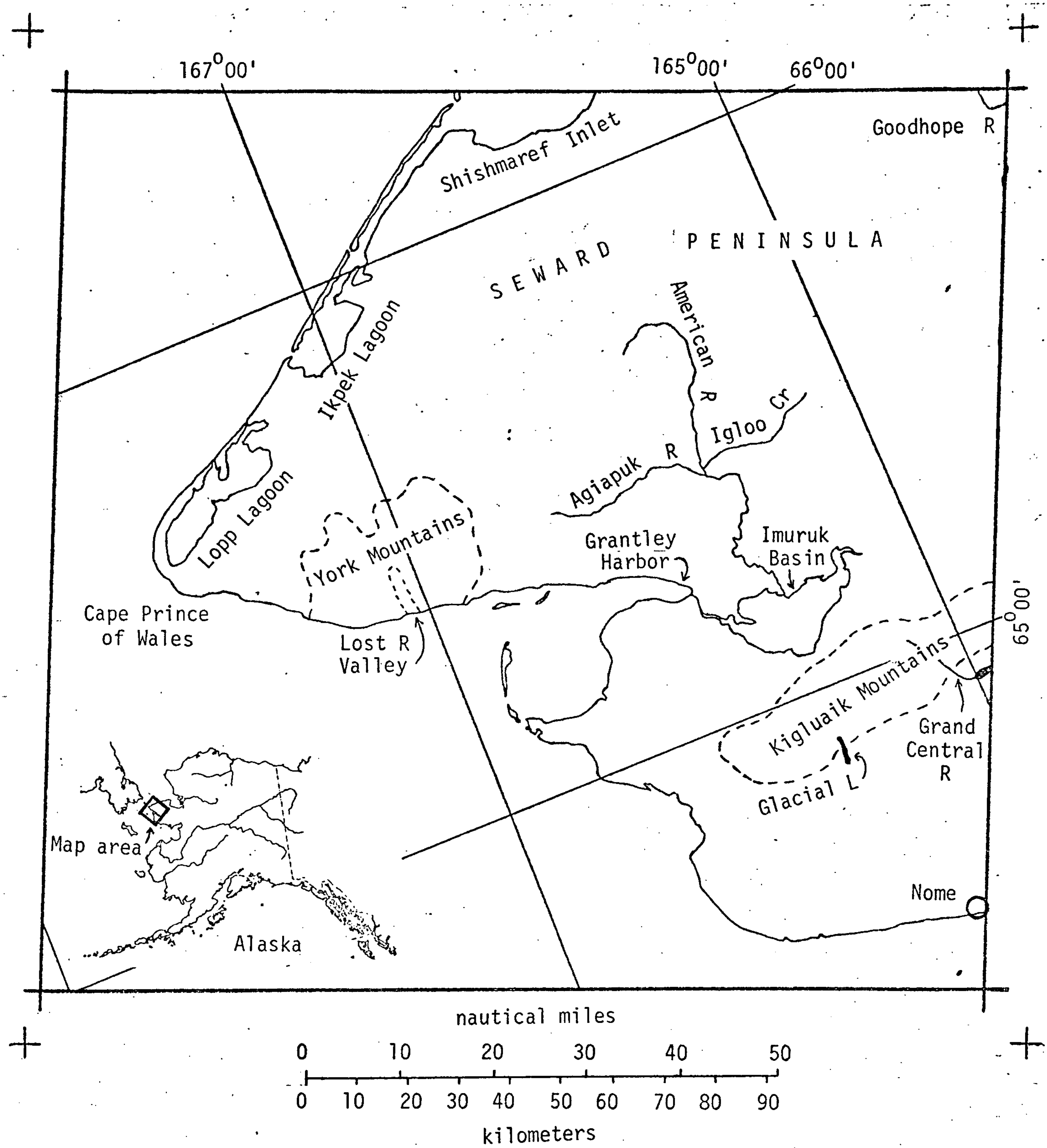

Figure 1. Map of the western Seward Peninsula, Alaska, showing geographic features mentioned in the text. This map was drawn by tracing on an acetate overlay of the ERTS-1 image. It is of the same scale and shows the same geographic features as are on the vegetation map, Figure 2.

The geographic coordinates of the scene are approximately 64°25' N X 165°25' W; 65°50' N X 163°50' W; 66°20' N X 167°50' W; 64°40' N X 169°10' W. A reproduction of the image is not included because of the prohibitive cost of making color copies. A copy could be obtained from ERTS User Services, Code 563, Building 23, Room E413, NASA/ Goddard Space Flight Center, Greenbelt, Maryland 20771. Readers in the University of Alaska area could borrow a copy from the ERTS data users' facility via the authors.

It is generally known (a) that vegetation covers all of the Seward Peninsula except for water surfaces, sandy areas, and rocky terrain, particularly at higher elevations and (b) that live vegetation in a normal physiological state appears on color-infrared photographs as some color of red, depending primarily on species composition, physiognomy and plant density (Knipling 1969; Haugen et al, 1972). Therefore on the image under consideration red colors are assumed to represent vegetation, with color differences representing differences in the vegetation parameters mentioned, hence in vegetation types. Six red colors are recognized and are believed to represent four vegetation types, albeit broadly defined types, and two vegetation-related phenomena. A seventh color, gray, is believed to represent terrestrial, primarily mountainous areas where vegetation is sparse or nonexistent.

In this report the term "color" is used in reference to tonal density, hue or shade. Only color, shape and pattern are recognized on the image. Texture is nondiscernable because of coarseness of resolution and thus is unavailable for vegetation interpretations. Haugen et al. (1972) were unable to discern texture for vegetation identification on a similar image of the nearby Koyukuk-Kobuk River area to the east whereon the resolution limit was judged at approximately 80m. In this regard it is noted that no roads or other cultural features can be recognized on the color image; however the western Seward Peninsula is sparsely inhabited and the existing roads are short and narrow. Nome (2,500 inhabitants), the only town in the area, is at the lower edge of the image and it is not discernible.

Ground truth is limited to the vegetation maps of Sigafoos (1958), Spetzman (1963) (Figure 3), Küchler (1966) and Viereck and Little (1972). These maps depict four broadly defined vegetation types which are generally comparable in distribution on each. Four of the colors are matched with these and identified accordingly. Identifications are supported by considerations of apparent topographic relationships and information in the limited literature. The possible identity of the three colors having no corresponding map units is discussed.

Potential sources of additional ground truth, such as aerial photographs and unpublished field observations and data of other workers, were dismissed at the outset because it was desired to determine the extent to which an investigation could meaningfully be conducted using only the simulated color-infrared image and readily available information. It is hoped that the results will be particularly valuable to workers with real limitations of this type.

Three maps are provided. The first, Figure 1, is a base map showing the locations of features mentioned in the text. The outline was traced on an acetate overlay of the ERTS image and the scale is therefore the same, approximately 1:1,083,400. The second, Figure 2, is the new vegetation map. This map was also drawn on the base map of Figure 1, and the vegetation information depicted was traced directly from the image. Figure 3 is a copy of part of the vegetation map of Spetzman (1963), enlarged and traced onto the base map of Figure 1. This map is provided for comparison with the new vegetation map.

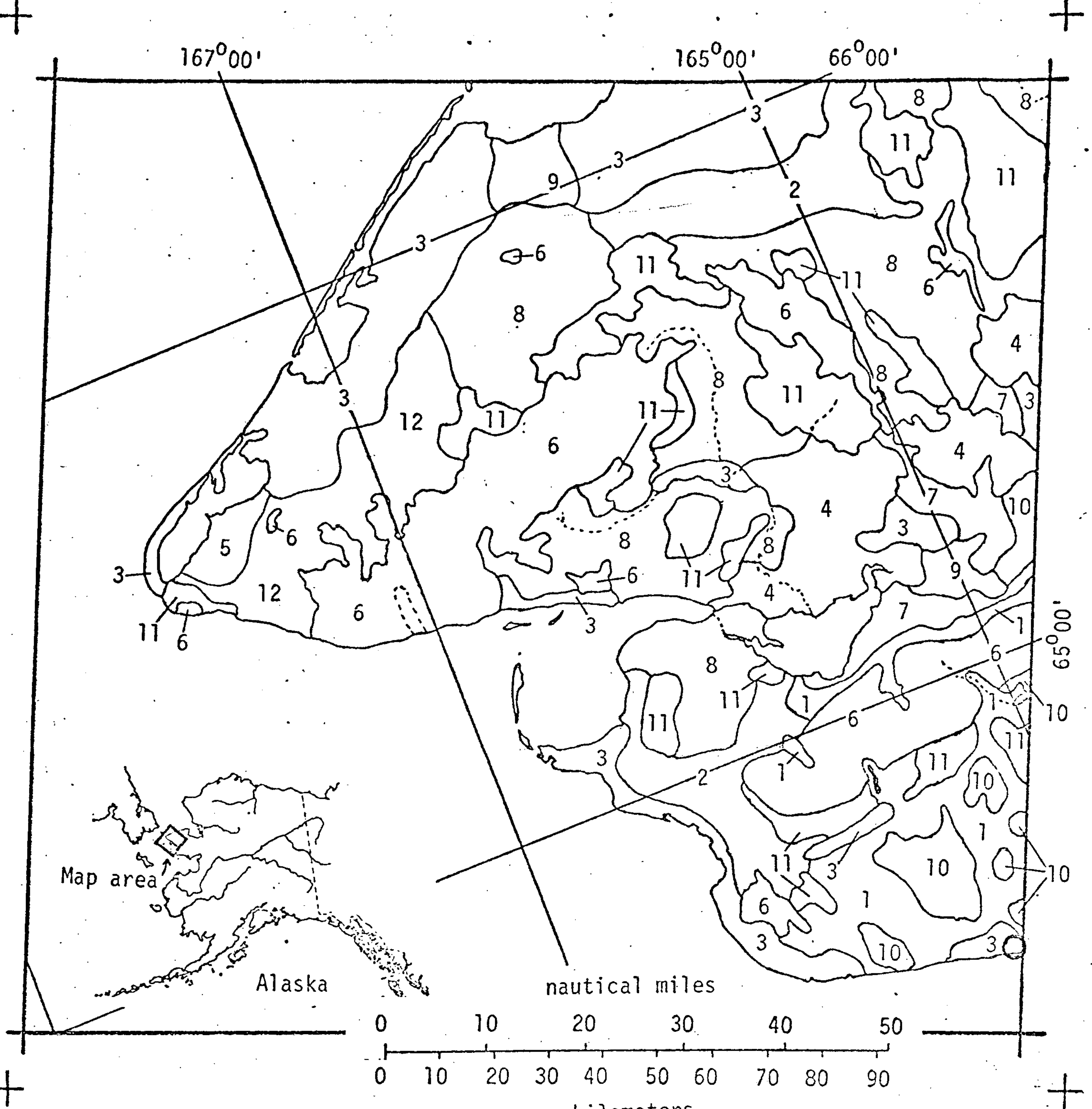

Figure 2. Vegetation map of the western Seward Peninsula, Alaska

Traced from an ERTS-1 image

1. Shrub thicket
2. Upland tundra
3. Wet tundra
4. Fire scar
5. Senescent vegetation (?)
6. Alpine barrens
7. Grassland tundra (?)
8. Shrub thicket/Upland tundra mosaic
9. Shrub thicket/Wet tundra mosaic
10. Shrub thicket/Alpine barrens mosaic
11. Shrub thicket/Upland tundra/Alpine barrens mosaic
12. Upland tundra with some senescent vegetation

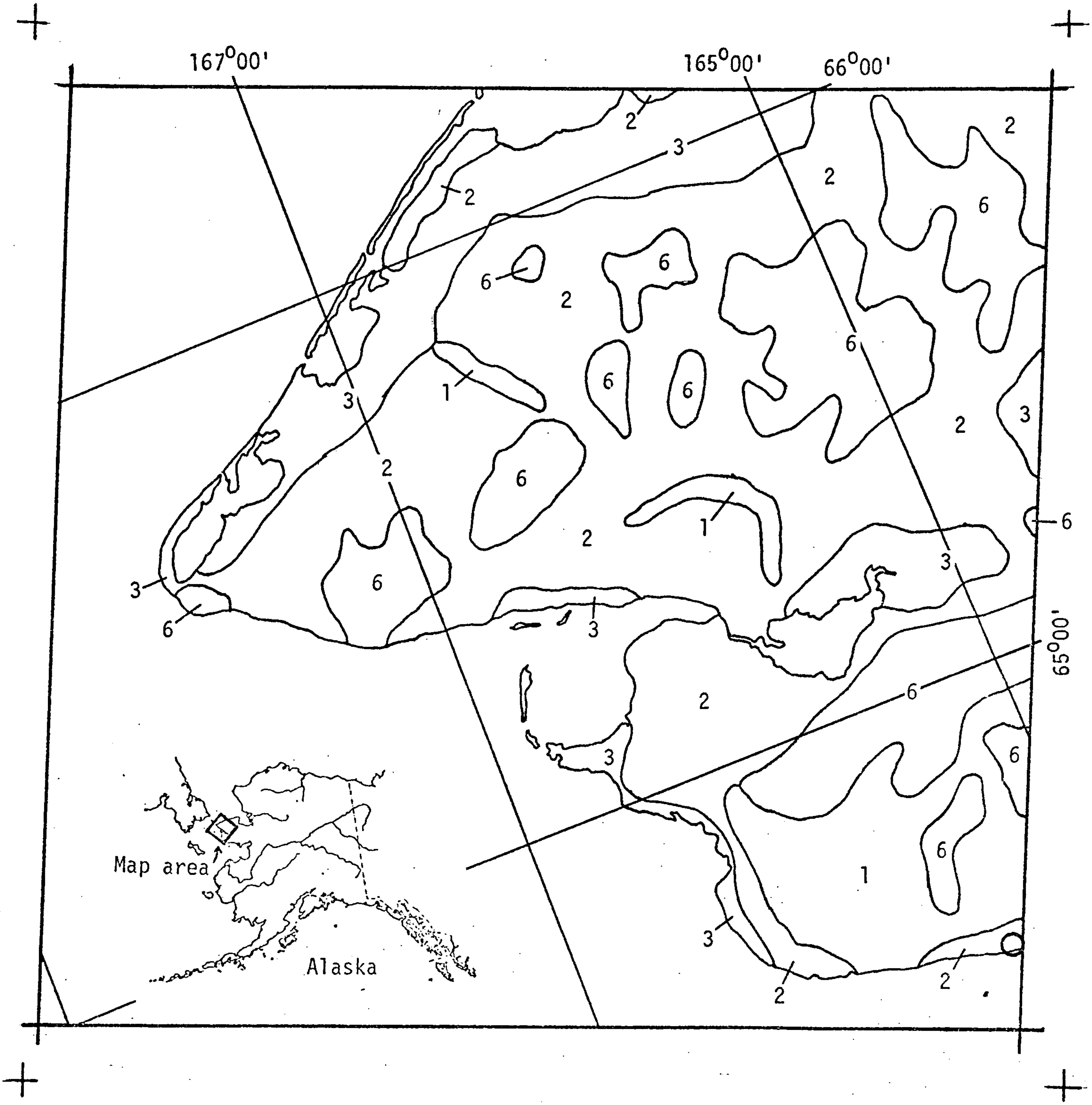

Figure 3. Vegetation map of the western Seward Peninsula traced and enlarged from Spetzman's (1963) map of Alaskan vegetation. This is provided for comparison with Figure 2. The map units designated by Spetzman and their approximate equivalents as termed in this paper are: 1. High brush - Shrub thicket; 2. Moist tundra - Upland tundra; 3. Wet tundra and coastal marsh - Wet tundra; 6. Barren and sparse dry tundra - Alpine barrens.

IMAGE PREPARATION

ERTS-1 scene number 1009-22095 was reconstituted in simulated color-infrared by photographing registered black and white positive transparencies successively through appropriate filters and using the Ektacolor process for producing an internegative color transparency and finished prints.

Owing to the very large density range and small format of the available 70mm NASA products, 240mm black and white positive transparencies with a smaller range of densities were made using the stepped density scale on the original negatives as a control for exposure and contrast. These transparencies, for MSS bands 4, 5 and 7 were placed in exact registration on a glass plate illuminated diffusely by a 3200° spotlight incident on a white lambertian screen placed at a 45° angle below the glass plate.

The registered positive transparencies were photographed successively as a multiple exposure on ektacolor type L negative film using a Polaroid MP-3 copy camera equipped with Kodak Wratten filters No. 47 (blue) for the MSS band 4 transparency, No. 58 (green) for MSS 5, and No. 25 (red) for MSS 7. The exposure was determined by pointing a reflected light meter at each of the transparencies and compensating for the bellows extension factor, filter factor, and reciprocity failure of the film material. The resulting color negative was processed according to Kodak recommended C-22 color negative processing chemistry procedures.

Up to this point the data handling technique was standardized and no attempts were made to change the density or color balance of the negative by changing the relative exposures of the three MSS bands either in the production of the black and white transparencies or in the production of the composite color negative. In achieving a balanced Ektacolor print from such a composite color-infrared negative, the only reliable guide is the gray scale that is included on all the NASA ERTS products. However this is not necessarily a valid criterion because prints which are not color-balanced may in fact enhance color difference areas which are related to vegetation or geologic patterns. Therefore Ektacolor prints with different color balances were produced. A subjective examination of these prints indicated that a balanced color print, slightly over-exposed, was best for vegetation identification and mapping.

OBSERVATIONS AND INTERPRETATIONS

Seven colors are identified on the simulated color-infrared ERTS image of the western Seward Peninsula (1009-22095).

1. Bright red

A good example of this color is a band across the lower northern slopes of the Kigluaik Mountains, southeast of Imuruk Basin. In other places it is associated with streams and upland lakes, such as the Grand Central River, Glacial Lake and several of the rivers flowing into Shishmaref Inlet and Ikpek Lagoon. This color is widespread as relatively small, elongate spots in upland areas throughout the scene. In many places these spots are connected in a dendritic pattern indicating an association with systems of smaller streams. In the southeastern part of the scene the bright red color is prevalent.

Bright red is believed to represent a shrub thicket vegetation type. Its distribution approximately matches that of woody vegetation depicted on U.S. Geological Survey topographic maps (Nome, Teller and Bendeleben sheets in the 1:250,000 series). There is general correspondence with the distribution of shrub dominated vegetation as depicted on the four vegetation maps. Particular reference is made to the southeastern part of the image area where bright red is prevalent and where these maps show a large area of shrub vegetation. Elsewhere, as along some of the larger northern rivers, the maps show smaller areas of shrub vegetation corresponding with the general occurrence on the image of bright red along rivers.

In the large area of the image there is probably a great deal of variation in composition and structure within the shrub thicket vegetation type. No indication of this variation can be seen on the image, except that the bright red color seems to have a violet hue in the south, as in the band across the northern slopes of the Kigluaik Mountains, whereas on the northern part of the image it is slightly orange. These two color phases, if real, may reflect differences in species composition. It is likely that in the south *Alnus* spp. and *Populus balsamifera* are more important than in the north, where *Salix* spp. and *Betula nana* may be the major shrub species. General knowledge of its topographic relations suggests that *Alnus crispa*, or possibly *A. sinuata*, is the predominant species in the vegetation represented by the bright red band across the northern slopes of the Kigluaik Mountains.

2. Light gray-red

This is the most widespread color on the image. It occurs in large continuous patches and as a matrix for other colors, particularly bright red, nearly everywhere except for the northwestern coastal zone and the mountains. On the southeastern part of the image it is secondary in areal importance only to bright red. The terrain represented by light gray-red appears primarily to be uplands, including most flat and non-steeply sloping areas above the coastal plains and valley bottoms and below the higher mountain slopes.

It is believed that light gray-red represents an upland tundra vegetation type. Its range approximately matches that of the type designated moist tundra by Spetzman (1963) and Viereck and Little (1972) and cottonsedge tundra by Küchler (1966). It is generally comparable with the range of the type termed herbaceous tundra by Sigafoos (1958), except where he extends this type through the northwestern coastal zone. Correspondence with the vegetation maps would be even closer were the range of the pink color, discussed below, combined with it.

It can be assumed from its wide distribution and variety in topographic position that upland tundra, even more than shrub thicket, is a diverse vegetation type, consisting of a large number of species in widely varying proportions. The species are predominantly herbs, including Carex spp., Eriophorum spp., grasses, and flowering dicots such as Dryas spp.; dwarf shrubs, including several heath species; and a variety of cryptogams. Unlike the shrub thicket type, however, no color phases which might indicate major variation within this type are positively discernable. Some color differences are detected, but the units are relatively small and local, they intergrade extensively, and it is difficult precisely to relate one to another across the scene.

It is probable that patterned ground phenomena are prevalent in this vegetation type, as these are common in upland tundra environments. Hopkins and Sigafoos (1951) indicate their predominance in the Imuruk Lake area about 40 km east of the present scene. Some patterned ground features, such as frost scars, peat rings and stone stripes, contain mineral soil and bare or dark lichen covered rock exposed at the surface. It is suggested that the gray component of the light gray-red color derives, at least in part, from these. Tussock development may be important in places, where water in inter-tussock hollows might also give rise to grayness.

3. Medium gray-red

This color appears as a wide band along the entire northwestern coast except for the area immediately east of Cape Prince of Wales, which is light orange-red. It occurs as a narrower band along parts of the southwestern coast, and it seems to occur in the area adjacent to the north side of Imuruk Basin. In the latter area the distinction from dark gray-red is not clear.

It is evident from its proximity to the sea and the abundance of lakes and ponds that the terrain represented by medium gray-red is low lying and poorly drained. A preponderance of surface water and saturated soil is believed responsible for the gray color component. Plants probably are standing in shallow water in many places.

The distribution of medium gray-red on the image approximately matches that of the wet tundra and coastal marsh of Spetzman (1963), the watersedge tundra of Küchler (1966) and the wet tundra of Viereck and Little (1972). It is concluded that this color fairly accurately represents this variously designated type, which for present purposes is termed the wet tundra vegetation type. According to information accompanying the maps, it consists predominantly of Carex spp. and several grass species. The apparently uniform topography and drainage indicates that variation in this type is minor, at least, in contrast to the highly variable upland tundra. Narrow strips of bright red color occur within predominantly wet tundra areas, representing low shrub vegetation along streams where ground water is more mobile and the permafrost table lower (Sigafoos 1958: Plate 13).

4. Dark gray-red

This color appears as three large patches north and northeast of Imuruk Basin. As was mentioned above, it may intergrade with medium gray-red north of Imuruk Basin. In most places the borders of these patches are abrupt and irregular, having no apparent topographic relationship. In other places streams form parts of their boundaries, as where the northwestern edge of the western patch is formed by Igloo Creek.

It is believed that the dark gray-red patches represent fire scars. The peculiar nature of their borders indicates this, and dark areas on color-infrared photographic imagery of other areas have been shown to indicate burned vegetation (e.g. Haugen et al 1972). It is generally known that tundra fires have occured on the Seward Peninsula within the past several decades. This conclusion is confirmed by records of the Bureau of Land Management which indicate, with one exception, a correspondence between areas burned in 1971 and the areas of dark red on the image.

The exception pertains to the southern part of the western patch, adjacent to Imuruk Basin on the north. The Bureau of Land Management has not recorded a burn in this area. Therefore the dark gray-red color here may reflect only wet, marshy vegetation, even though the color is different from other areas of the wet tundra vegetation type. It is also noted that the western extension of this area, including a dark gray-red tongue reaching Grantley Harbor, seems to lie on upland terrain and to have the apparently random boundaries of a former burn.

5. Light orange-red

The main area of this color is around Lopp Lagoon in the vicinity of Cape Prince of Wales. Southeast of here, in the vicinity of the York Mountains, it forms a matrix for small patches of bright red and light gray-red colors. An orange cast appears in the coastal wet tundra in the vicinity of Ikpek Lagoon, and a slight orangeness appears in the upper Lost River valley and throughout much of the area between Grantley Harbor and the western Kigluaik Mountains.

The main area of light orange-red and the other areas of basically different colors with an orange cast correspond with no map unit. The interpretation of this color must therefore be based on other considerations. A low amount of redness could be due to sparse vegetation cover, in which case the color observed could represent a ground surface of a predominantly mineral nature. The possibility that the surface here, in this coastal environment, is primarily of sand and larger aggregates was considered. A sand dominated landscape with sparse vegetation occurs at places in, for example, the Prudhoe Bay area. However, on the surficial geology map of Alaska (Karlstrom et al 1964), there is no indication of such a landscape on the western Seward Peninsula. Furthermore, Haugen et al. (1972) show that sand dunes appear a light blue on the Koyukuk-Kobuk River area image. Finally, were the vegetation in the area under consideration truly distinct, it is likely that it would be so depicted on the vegetation maps. The area is sufficiently large to have been mapped even at the relatively small map scales.

It is suggested that the light orange-red color represents senescence in vegetation types already identified: coastal wet tundra near the sea and upland tundra elsewhere. The image under consideration was obtained on August 1. It is possible that killing frosts had occurred in this area just prior to this date, thus initiating the loss of chlorophyll from plant tissues. Although the growing season for the Seward Peninsula in general normally extends to a later date (Hopkins and Sigafoos 1951: 55), lower summer temperatures and a shorter growing season probably prevail in the exposed, maritime environment of Cape Prince of Wales as compared with coastal areas farther south and interior areas where no orange cast yet appears.

That the loss of chlorophyll from plant tissues may result in a decrease of red on color-infrared imagery is indicated by October photographs from the Forestry Remote Sensing Laboratory, etc. (1972) upon which alfalfa and cotton fields appear orange-brown.

6. Gray

This color, in several shades, is that of mountains and higher elevation areas generally above the upper limit of continuous vegetation cover. The distribution of this color matches that of Sigafoos' (1958) map unit, rock desert, sand plains and bare rock. It compares with the barren and sparse dry tundra of Spetzman (1963), the dryas meadows and barrens of Küchler (1966) and the alpine tundra of Viereck and Little (1972). In this paper the vegetation in the areas represented by gray is referred to the subarctic alpine barrens type. (This term emphasizes a location at higher elevations in the subarctic zone.) Areas of more or less continuous plant cover lying within the general barrens area are referred to the upland tundra vegetation type. On further analysis, however, these areas might be recognized as belonging to a distinct subarctic alpine tundra type.

Vegetation cover in the alpine barrens type is sparse, with the result that faint or no red color is seen. Gray represents surfaces chiefly of bedrock and partially weathered and broken down rock in various geomorphic categories. In the mountains north and northwest of Imuruk Basin limestone predominates (Dutro and Payne 1957), and the color here is a light gray. Darker gray colors appear in the Kigluaik Mountains where there are other rock types at the surface. In a few small areas non-red colors other than gray are seen, indicating, for example, granitic intrusions, but these also are mountainous areas where the plant cover presumably is sparse.

7. Pink

This color, a light to medium red and very smooth textured is represented by a band contiguous on the north with the previously referenced band of bright red across the lower northern slopes of the Kigluaik Mountains. It is also recognized in the main valleys and on the south flank of this range. A relatively large pink area occurs adjacent to the many ponded lowlands around Imuruk Basin on the northeast. Pink areas occur elsewhere, e.g. the large area in the mountains east of the upper American River, but here they appear to be the result of darker red colors showing through thin cloud cover.

It is cautiously hypothesized that the pink color represents a grassland tundra vegetation type. As indicated above, this color appears to occur as a relatively minor feature within the range of upland, herbaceous tundra vegetation types as depicted on the vegetation maps. Therefore it may represent a variant of upland tundra, possibly one wherein soil frost action and surface water are relatively unimportant. The absence of grayness may indicate the latter. Where soil is more stable and better drained vegetation may contain a high proportion of grasses. Grass species are known in other areas to appear a bright pink on color-infrared photographs (e.g. see illustrations in Laboratory for Agricultural Remote Sensing, etc. 1970).

A grassland tundra hypothesis was advanced by Guthrie (1968) for the late Pleistocene of interior Alaska. He suggests from paleontological evidence that such a vegetation type occupied major portions of interior Alaska then and served as a major food source for many now-extinct large mammal species. It seems possible that some areas of the Seward Peninsula have a climate similar to that of interior Alaska during the late Pleistocene and are therefore favorable for the development of a similar vegetation. It is noted in this regard that the present grassland tundra of much of the arctic slope of Alaska, as in the vicinity of Barrow and Prudhoe Bay, may be wetter and existing under a cooler climatic regime than the type suggested here. In any case, the appearance of the arctic slope grassland tundra on simulated color-infrared ERTS imagery is not yet known.

DISCUSSION

The accuracy of the interpretations will be unknown until additional ground truth is brought to bear on them. Conventional aerial photography may provide the necessary information, and there undoubtedly is photography available for the western Seward Peninsula. Ground observations, however, are especially desirable, particularly as a few critical areas selected with the aid of the ERTS image could readily be visited. These include the Nome area, the northern flank of the Kigluaik Mountains east of Imuruk Basin, the area north of Imuruk Basin, the area just inland from Lopp Lagoon and the area around Ikpek Lagoon. The desired information might be obtained visually by flying low over these areas in a light aircraft. A loop trip out of Nome of about two hours duration should suffice to verify the accuracy of the photographic interpretations presented in this report.

Notwithstanding the lack of ground truth, this exercise indicates that a significant amount of vegetation and other landscape information may be obtained from ERTS imagery by direct visual examinations of photographic prints. A number of major colors can readily be discriminated, and some variation within these can also be seen as color phases. All that is needed is adequate lighting, normal color vision and a well prepared print. A low power magnifying glass is helpful. A stronger glass, such as a ten power hand lens, may be of some further aid.

Of the seven colors recognized on the western Seward Peninsula image, one, bright red, appears with two phases, violet and orange, which are believed to indicate major differences in species composition. The other colors showed variation too, but it is not possible to establish precise color phase definitions because of widespread interblending and the inability of the examiner to identify with reasonable certainty the color of a small patch in one place as the same as, or different from, that patch in a different place. Herein seems to lie the chief limitation of simple visual examination of ERTS imagery. To increase information derivation, various photographic, optical and digital image enhancement techniques must be employed.

The ERTS image studied provides considerably more information about vegetation than the existing vegetation maps, a fact which is significant in terms of the large amount of area covered. A great deal of information could, of course, be obtained from conventional aerial photography, but only at a formidable cost.

If the present interpretations are correct, the distributions of the four vegetation types depicted on the existing maps are shown in greater detail on the image and on the new map presented here, and thus a better impression of their actual areal importance is at hand. The shrub thicket type, for example, is seen to be quite widespread, particularly as it occurs as numerous stands in upland drainageways throughout the scene. These stands are too small to draw on any but local, large scale vegetation maps. Nevertheless, they collectively occupy a significant amount of area. On the present map they are included in mosaic units, units 8-11. More detail in the distribution of the subarctic alpine barrens type may also be seen on the image. Whereas on the maps the mountain ranges bearing this type are simply encircled, these barrens appear on the image rather intricately interpenetrated with valleys containing a denser vegetation type, primarily upland, or alpine, tundra.

Besides the more accurate areal assessment of known vegetation types depicted on the existing maps, an additional type, possibly a grassland tundra, is recognized through visual examination of the ERTS image. Further information which seems to be available at the present level of examination pertains to the fire history of the landscape. The distribution of past fires in this large area may be determined almost at a glance because of the distinctive dark gray-red color of burned areas. It is noted, however, that the maximum time that an area remains recognizable as burned is not known, the burn areas identified here being only one year old. Secondary vegetation succession presumably occurs, ultimately to restore an appearance or color which may or may not be distinguished on ERTS imagery from that of non-burned areas, depending on whether the same or different species grow back. In another area of Alaska a spruce forest burn which occurred fifty years ago is readily recognizable on a color-infrared ERTS image because willows and aspens replaced the spruce forest in the burned area. A related unknown factor is the original degree of vegetation destruction wrought by a fire, hence of loss of red color.

It is suggested that where extensive vegetation destruction by a fire is known to have occurred and the early post-fire color is dark gray-red or gray-black, the degree of recovery might be estimated from the amount of redness. On the other hand, in the case of a recent or current fire it is suggested that the extent of vegetation destruction or fire intensity might be estimated by the same parameter. For example, it should be possible to distinguish creeping ground fires from crown fires in areas of Alaska which are more heavily forested than the Seward Peninsula. Future sequential ERTS imagery seems to hold promise for monitoring the development and spread of vegetation fires, hence of contributing to management procedures. Haugen et al (1972) indicate the rate of increase in size of a current burn in the Koyukuk-Kobuk River area.

Finally, and of considerable importance, the ERTS image seems to provide phenological information. As is indicated above, the light orange-red color may represent senescent vegetation. If so, the spatial gradation in intensity of this color, as between the shore of Lopp Lagoon and the northwestern foothills of the York Mountains, suggests that the ERTS system also is sensitive to degree of senescence. A seasonal sequence of images might therefore provide a chronological and spatial survey of the development and deterioration of green plant material. This would be useful as an indication of prevailing weather conditions.

SUMMARY

A reconstituted, simulated color-infrared image covering the Western Seward Peninsula is used for identifying and mapping vegetation types by direct visual examination. The image, NASA ERTS E-1009-22095, was obtained at 1110 hours on August 1, 1972. The 1:1,083,400 photographic print used was prepared by a color additive process with MSS positive transparencies for bands 4,5 and 7.

Seven major colors are identified. Four of these are matched with four units on existing vegetation maps: Bright red - shrub thicket; light gray-red - upland tundra; medium gray-red - coastal wet tundra; gray - alpine barrens. In the bright red color two phases, violet and orange, are recognized and tentatively ascribed to differences in species composition in the shrub thicket type. The three colors having no map unit equivalents are interpreted as follows: Pink - grassland tundra; dark gray-red - burn scars; light orange-red - senescent vegetation.

It is concluded (a) that ERTS imagery is useful for studying diversity and distribution of vegetation types, (b) that this is a feasible basis for quickly drawing or revising vegetation maps, (c) that sequential imagery should permit evaluation and monitoring of vegetation fires and phenologic events and (d) that direct visual examination of ERTS imagery, in lieu of more sophisticated analytical procedures, can enable significant interpretations. A new vegetation map at the same scale as the image, drawn by tracing on an acetate overlay, is provided.

ACKNOWLEDGEMENTS

The work reported herein was performed under National Aeronautics and Space Administration Research Contract No. NAS5-21833: An interdisciplinary feasibility study of the application of ERTS-A data to a survey of the Alaskan environment. The authors thank Keith Van Cleve and Leslie A. Viereck for critically reading the manuscript and providing certain information.

LITERATURE CITED

Dutro, J. T. Jr., and T. G. Payne. 1957. Geologic map of Alaska. U. S. Geological Survey, Washington, D. C.

Forestry Remote Sensing Laboratory, University of California, Berkeley 1971. A training program in aircraft and spacecraft remote sensing for scientists and resource managers of the U.S. Department of the Interior: A course syllabus. Forestry Remote Sensing Laboratory, University of California, Berkeley. Numerous pages and illustrations.

Guthrie, R. D. 1968. Paleoecology of the large mammal community in interior Alaska during the late Pleistocene. American Midland Naturalist 79: 346-363.

Hanson, H. C. 1953. Vegetation types in northwestern Alaska and comparisons with communities in other arctic regions. Ecology 34: 111-140.

Haugen, R. K., H. L. McKim, L. W. Gatto and D. M. Anderson. 1972. Cold regions environmental analysis based on ERTS-1 imagery. Preprint, Proceedings of the 8th International Symposium on Remote Sensing of Environment, University of Michigan, 2-6 October, 1972. U. S. Army Cold Regions Research and Engineering Laboratory, Hanover. 12 p.

Hopkins, D. M. and R. S. Sigafoos. 1951. Frost action and vegetation patterns on Seward Peninsula, Alaska. U. S. Geological Survey Bulletin 974-C: 51-101.

Hultén, E. 1968 Flora of Alaska and neighboring territories. Stanford University Press, Stanford. 1,008 p.

Karlstrom, T. N. V. and others. 1964. Surficial geology of Alaska. U. S. Geological Survey, Washington, D.C. Map, 2 sheets.

Knipling, E.B. 1969. Leaf reflectance and image formation on color infrared film, p 17-29. In P. L. Johnson, Ed. Remote Sensing in ecology. University of Georgia Press, Athens. 244p.

Küchler, A. W. 1966. Potential natural vegetation of Alaska. U. S. Geological Survey, Washington, D. C. Map.

Laboratory for Agricultural Remote Sensing, Purdue University, 1970. Remote multispectral sensing in agriculture. Laboratory for Agricultural Remote Sensing Annual Report - Volume 4. Purdue University, Lafayette. 112 p.

National Aeronautics and Space Administration. 1971. ERTS data users handbook (with revisions). National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland.

Sigafoos, R. S. 1951. Soil instability in tundra vegetation. Ohio Journal of Science 51: 281-298.

Sigafoos, R. S. 1958. Vegetation of northwestern North America, as an aid in interpretation of geologic data. U. S Geological Survey Bulletin 1061-E: 165-185.

Spetzman, L. A. 1963. Terrain study of Alaska, Part V: Vegetation. U. S. Geological Survey, Military Geology Branch. Department of the Army, Office, Chief of Engineers, Washington, D.C. Map.

Viereck, L. A. and E. L. Little, Jr. 1972. Alaska trees and shrubs. U. S. D. A. Forest Service Agriculture Handbook No. 410, 265 p.